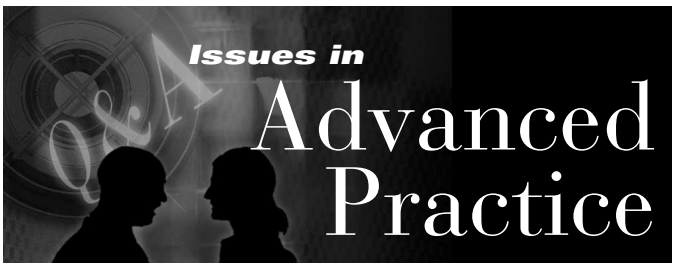

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The Use of Computer Decision Support Systems for the Critical Care Environment

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Question

My colleagues and I have been talking about the future of computerized decision support and how it may impact us. Can you give us more information about how this currently works and the related benefits and burdens?

Answer

As the workload of primary care providers continues to increase, the use of automation in the intensive care unit (ICU) environment has been touted as a way to increase effectiveness of patient care and standardize practice, while reducing the number of complications associated with the use of manually implemented approaches.[1–4] Medical computer decision support (CDS), or computer decision assist, applications are a type of information technology system that embed the expertise of experienced care providers and/or standards of care into a computerized system. They can be implemented at any care level including prehospital, emergency departments, operating rooms, and ICUs. These systems provide information on patient care issues as an adjunct to standard treatments used during the patient's stay. For example, a typical CDS system may provide alerts when a combination of patient parameters fall out of range and recommend changes in drug rates to the care provider to bring the patient parameters within acceptable limits. By providing clinicians with these types of applications, patient care is improved in 2 ways. First, they provide a tool for learning and quality improvement. These systems provide the ability to push the expertise of more experienced care providers to clinicians who may not be fully trained or may be unfamiliar with current evidence based practice (EBP) guidelines. Second, as a decision support adjunct, these systems provide additional information that may not be otherwise available or easily obtainable to experienced care providers. Computer decision support systems improve the provider's ability to manage multiple sources of data, allow for trending analysis, and provide the ability to fuse data from multiple sources. Furthermore, these tools allow for advanced information processing that can be used in predictive modeling of patient outcomes. By combining multiple data sources, analyses such as multivariate regression, artificial intelligence, neural

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networks, decision trees, support vector machines, and other machine learning techniques can be utilized by the software to increase the reliability and effectiveness of different diagnostic approaches in the critical care environment.

Types of Decision Support Systems

There are several types of decision support systems based on the application environment (Table 1). Data-driven systems can translate raw data and numbers into meaningful information, deriving conclusions that would normally not be practical for a typical user. Trending, grouping, summarizing, and associated methods to process and mine raw data are some examples. The advantage of these systems is in the ability to fuse large data sets in a clinically meaningful way; however, these systems typically do not provide the user with recommendations. The user is expected to translate the processed information in the clinical scenario and intervene appropriately. Another type of CDS is a knowledge-driven decision support system. Both of these systems provide the user with the knowledge (either from an expert or from an EBP guideline) on a particular topic. However, the system is only as good as the knowledge that is embedded; inaccuracies and partial knowledge that exist in the underlying rules will continue to exist and be utilized by the system.

Control CDS systems interpret real-time patient data to predict future patient response based on mathematical analysis of the trend. Examples include software designed to direct titration of insulin[5–8] or infusion of resuscitation fluids for hypotension or burn shock management.[9,10] Human-user interface is required to verify and accept system recommendations because in many cases the clinical scenario will be complicated, and inputting all clinically relevant parameters in the computer system is unworkable. When the clinical scenario is considered routine, a closed-loop approach may become practical. These types of systems remove the clinician from the treatment loop and implement complete control using a computer to sense, process, decide, and act on the appropriate treatment for the patient without human intervention. An example of this type of system that has been successfully implemented includes mechanical ventilators that incorporate closed-loop technology for ventilator weaning.[11] Other systems to provide blood gas or end-tidal carbon dioxide monitoring as a feedback mechanism for ventilation[12] and oxygenation[13] have been proposed.

Decision Support Systems for Medical Use

It was quickly realized that one area ripe for use of CDS systems was in the medical arena. Implementation of best practices remains a challenge, and providers in our complex clinical environment can be overwhelmed with countless pieces of individual data that fail to give a meaningful picture of a patient's progress. A mean arterial blood pressure of 68 mm Hg could be favorable if the patient is on vasopressor agents, yet this same reading could be unfavorable if the previous trend was

Table 1: Types of Computer Decision Support (CDS) Systems

CDS Type	Advantages	Disadvantages	Examples
Data driven	Provides data aggregation, trending, and clustering	User must interpret data results and their meaning	Graphical trending of vital signs or laboratory values
Knowledge driven (rule based)	Uses available knowledge (rules and experiences) to make decisions and recommendations	Can be biased to the rules used	Disease diagnostic systems
		Limited to what the rules implement	Electrocardiographic interpretation
		May not handle situations outside local knowledge	Biosurveillance systems
Control	Separates the user from the treatment of the patient during "routine" case	Many cases are complicated	Anesthesia systems
		May require additional parameters unavailable to the system	Ventilator circuit
			Closed-loop glycemic control

closer to 90 mm Hg. Using computer algorithms for trending analysis improves an ICU nurse's recognition of negative trends, allowing for earlier intervention. The concept of using a computer interface dashboard for displaying critical values based on the patient's problem list provides a snapshot of trends and highlights critical values for the provider.[1] Such aggregation of data by a decision support system will improve a novice ICU nurse or medical resident's identification of meaningful trends. Use of computerized systems has been demonstrated to improve compliance with best practices and improve practitioner performance.[2] More research is needed to determine the effect of CDS systems on patient outcomes,[2] but improvement in the consistent delivery of EBP treatment using computerized systems has the potential to improve delivery of care and ultimately reduce errors.[14]

Features critical to the success of decision support systems have been identified by Kawamoto and colleagues[3] through a systematic review of published studies (Table 2). Fifteen features were identified from the studies, with 4 elements being critical for a successful CDS: incorporating decision support systems with clinical workflow practices; providing recommendations in addition to assessments; implementing decision support at the appropriate time and location of the decision-making need; and use of computerized support. Systems that possessed all 4 characteristics (30 of 32 systems, 94%) significantly improved clinical practice.[3] Systems for computerized glycemic management of the ICU patient on a continuous insulin infusion are commercially available and have reported improved target glucose control and reduction in hypoglycemic events.[5–8] The nurse enters the patient's current blood glucose value, and the system recommends an insulin rate based on the trend over several hours; the nurse may accept or reject the system recommendation on the basis of the overall clinical scenario. These systems meet all 4 of the above-identified criteria for success.

The Future of CDS

Integration of technology is inevitable and essential in our complicated critical care environment. Qualitative analysis of CDS system acceptance by advanced practice nurses

Table 2: Potentially Important Features of Computer Decision Support (CDS) Systems[a]

General system features	Integration with charting or order entry system
	Computer-based generation of decision support[b]
	Local user involvement in development process
Clinician-system interaction features	Automatic provision of decision support as part of workflow[b]
	Provision at time and location of decision making[b]
	Request documentation of reason for not following recommendation
	Additional clinician data entry unnecessary
	Recommendations accepted by noting agreement
Communication content features	Provision of a recommendation, not just an assessment[b]
	Promotion of an action rather than inaction
	Justification via provision of research evidence
	Justification via provision of reasoning
Auxiliary features	Provision of decision support results to both clinicians and patients
	CDS accompanied by periodic performance feedback
	CDS accompanied by conventional education

[a]Adapted from Kawamoto et al.[3]

[b]Indicates features significantly associated with improved clinical practice.

suggests that the objective, scientifically derived, and technology-based recommendations support their clinical decisions and provide a useful tool in practice.[15] Sitting and his colleagues[16] have identified 10 future challenges for development of CDS systems that include improving the human-computer interface, summarizing patient-level information, and creating Internet-accessible CDS repositories and ability to mine large patient databases to create new CDS systems. It is for the end user (the nurses and physicians) to recognize the potential opportunities for improving efficiency and maximizing patient outcomes to drive the development of user-friendly systems that help rather than hinder ICU workflow. We are limited only by our imagination.

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